The Effects of Prenatal Care Upon the Health of the Newborn

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Abstract: Data upon all births and infant deaths in New York City in 1968 are analyzed using methods for the analysis of multidimensional contingency tables. These methods provide estimates of the effect of variations in prenatal care upon the relative risks of low birth weight and neonatal and postneonatal mortality, controlling for a wide variety of factors which tend to "select" women into a program of prenatal care. Significant relationships between lack of prenatal care and infant mortality are estimated, but these occur mainly via the relationship of inadequate prenatal care to low birth weight. Furthermore, among white mothers who delivered on a private service, those receiving inadequate levels of prenatal care experienced only slightly increased risks of a low birth weight infant. In contrast, white mothers who delivered on a general service, and all black mothers, experienced substantially increased risks when receiving inadequate prenatal care.

A variety of behavioral characteristics of mothers were not controlled in these analyses, and thus clear causal inferences concerning the efficacy of prenatal care cannot be drawn. These analyses do, however, identify a significant population of women at substantial risk. (*Am J Public Health* 69:653–660, 1979.)

Introduction

What role does prenatal care play in the prevention of infant mortality and morbidity? Do variations in such care play a major part in the conditioning of infant risk, or are these variations in risk structured for the most part by characteristics and behaviors which mothers and infants bring with them to the health care setting? Standard guides for the practice of maternal and infant health care stress the importance of such intervention,[1,2] yet research upon this question has provided mixed findings. Some research has downplayed the positive effects of prenatal care in reducing the risk of low birth weight and neonatal mortality.[3,4] In contrast, a "before and after" intervention study indicated some positive results when a program of prenatal care was introduced into a disadvantaged community.[5] The most sophisticated study completed thus far upon this question utilized data upon all births and infant deaths in New York City in 1968, and reported strong and consistent associations between a three-factor maternal health services index, and low birth weight and neonatal and postneonatal mortality.[6] Problems of methodology and inconsistent results, however, hamper interpretation of all these research efforts. The intervention study documented decreases in the incidence of low birth weight and neonatal mortality, but it was not possible to tell whether it was the infants receiving prenatal care who fared better.[5]

The 1968 New York City study, sponsored by the Insti-

tute of Medicine, found that relationships between a maternal health services index and postneonatal mortality were as great as those found between the index and low birth weight and neonatal mortality. Because prenatal care should exert a minimal influence upon postneonatal mortality, these results were interpreted as indicating that "the three-factor maternal health services index reflects health services received by mother and child and specific prenatal care, as well as an array of other maternal, social, behavioral and economic characteristics."[6] There is the strong suggestion in these comments that lack of control for selective factors which sort mothers into a system of prenatal care was responsible for the invalid results and, thus, that the estimated effects of prenatal care were overstated.

The present analysis attempts to correct some past deficiencies: the 1968 New York City data are subject to reanalysis using methods for the analysis of multidimensional contingency tables.[7–9] Relative risks of low birth weight and neonatal and postneonatal mortality are estimated for different levels of prenatal care received by mothers, controlling for a wide variety of available social, demographic, and medical factors which tend to select mothers into getting or not getting prenatal care.

Data and Methods

The data come from all birth and infant death records in New York City in 1968 and in general are of excellent quality.[6] Analysis is restricted here to the native white and native black populations of New York City, giving a total sample of 90,339 births, including 9,512 low birth weight infants, plus 1,447 neonatal and 482 postneonatal deaths.

The adequacy of prenatal care is defined according to criteria developed in the Institute of Medicine study,[6] which are based upon standards of care recommended by the American College of Obstetricians and Gynecologists.[2] These criteria adjust the number and timing of prenatal care visits to gestation period (see Appendix A), and classify care as either inadequate, intermediate, or adequate. The distribution of native black and native white mothers of infants born in New York City in 1968 into these categories is given in Table 1. It should be noted that the index used in the original Institute of Medicine study included an additional criteria in that mothers who were admitted to the hospital on a ward, as opposed to a private service, were classified as having received inadequate levels of care. This variable—a measure of the continuity of care received—is included in the present analysis as a separate variable. It should also be noted that the classification scheme does not attempt to scale the content of care received by mothers; the analytic focus is rather upon the inadequate care category, and thus upon the lack of any content or lack of any care received.

Ideally, the efficacy of prenatal care could be investigated through experiments which include random assignment of expectant mothers to prenatal care or to a condition of no prenatal care. Such experiments are not possible for obvious ethical reasons. The present approach attempts to approximate such a design by employing methods for the analysis of multidimensional contingency tables.[7-9] These methods allow the analyst to control, or hold constant, the effects of the variables available for study which are related to both prenatal care and to the outcomes of interest. Lack of random assignment to prenatal care conditions in the present research design makes the application of such controls imperative. Analysis of the New York City data (shown later in Appendix B) for example, indicates that the variables educational status of mother and father, age of the mother, birth order of the child, and wedlock status all significantly predict the adequacy of prenatal care received by mothers of infants included in the study. Mothers with 0-8 years of education, with similarly educated husbands, who are less than age 20, for example, experience a 7.5 times greater chance of receiving inadequate prenatal care than do mothers with a high school education or more, with similarly educated husbands, who are 31 years of age or older (holding constant the effects of birth order, wedlock status, and medical conditions observable during pregnancy).

It should also be noted that gestation length of the pregnancy is controlled in the construction of the prenatal care index, and thus its effects are also held constant when the effects of prenatal care are being assessed.

Three outcomes of birth are predicted: 1) the odds of a low birth weight infant (weighing less than 2500 gm. at birth); 2) neonatal mortality (deaths to infants during the first 27 days of life); and 3) postneonatal mortality (deaths to infants occurring 28 days through 11 months after birth). In the case of neonatal and postneonatal mortality, live births are taken as the exposed population. In the case of low birth weight, the dependent variable is the odds (approximately the probability) of a low birth weight versus all other births.

The independent, or control, variables include the fol-

TABLE 1—The Adequacy of Prenatal Care Received by Mothers of Native White and Native Black Infants Born in New York City in 1968

Adequacy of Prenatal Care	Native White		Native Black	
	N	%	N	%
Inadequate	10,167	17.0	14,420	46.9
Intermediate	22,186	37.2	13,014	42.4
Adequate	27,327	45.8	3,285	10.7
TOTAL	59,680	100.0	30,719	100.0

lowing: prenatal care received by the mother, educational attainment of mother and father, age of mother, birth order, wedlock status, medical conditions observable during pregnancy, type of hospital service, and (in the equations predicting infant mortality) birth weight. The values taken by these variables are given in Appendix B, Tables B1 and B2.

Prenatal Care, Low Birth Weight, and Infant Mortality

Estimated coefficients for equations predicting low birth weight and neonatal and postneonatal mortality, for both the native black and native white populations of New York City in 1968, are given in Appendix B, Tables B1 and B2. Coefficient estimates are also given for equations predicting who is delivered on a ward versus a private service and who receives inadequate prenatal care.

Coefficient estimates from these equations may be interpreted in terms of relative risks;[10] Table 2 displays estimates of the relative risk of low birth weight (more precisely, the odds ratio of a low birth weight), and neonatal and postneonatal mortality associated with differing levels of prenatal care. These estimates are derived from the multivariate logistic models (see Appendix B), and thus the first order (non-interactive) effects of all independent variables have been controlled. Hence, these are called adjusted estimates.

The estimates given in parentheses are unadjusted relative risks; these may be compared with the adjusted relative risks to gain an understanding of the effect that lack of random assignment of mothers to levels of prenatal care has upon the resulting estimates. For example, within both the native white and native black populations of mothers, the estimated relative risks of low birth weight associated with inadequate (as opposed to adequate) prenatal care are attenuated when adjusted for differences in composition between these populations. Within the native white population, the estimates change from 1.72 to 1.41, and within the native black population they change from 1.89 to 1.78.

Even more dramatic, however, are changes in the estimated relative risks of neonatal and postneonatal mortality. When controls are imposed (all background variables including birth weight are included in the equations), prenatal care is not significantly related to these outcomes, except in the case of the neonatal mortality of native black infants. This finding suggests that if prenatal care exerts any effect upon infant mortality, it is likely that this occurs via the effects of variations in prenatal care upon low birth weight. This find-

TABLE 2—Estimated Relative Risks of Low Birth Weight and Neonatal and Postneonatal Mortality by Adequacy of Prenatal Care in New York City in 1968, Adjusted for a Variety of Selective Factors‡

Population and Adequacy of Care	Estimated Relative Risks		
	Low Birthweight	Neonatal Mortality	Postneonatal Mortality
Native White			
Inadequate	1.41 (1.72)	1.06 (1.78)	1.04 (2.13)
Intermediate	.96 (1.02)	.87 (.94)	.90 (1.17)
Adequate	1.00 (1.00)	1.00 (1.00)	1.00 (1.00)
χ^{2b}	83.75**	3.62	.83
Native Black			
Inadequate	1.78 (1.89)	1.20 (1.89)	1.25 (1.75)
Intermediate	1.12 (1.18)	.87 (.86)	.92 (1.06)
Adequate	1.00 (1.00)	1.00 (1.00)	1.00 (1.00)
χ^{2b}	223.42**	26.68**	5.84

* = significant at .05
** = significant at .01

aThe standard used in all cases is the Adequate Care category for each population/outcome category.

bχ^2 tests are the likelihood ratio statistic, and indicate whether the vector of coefficient estimates from which these relative risks are derived are significantly different from zero. Two degrees of freedom are associated with all of these χ^2 tests.

‡See text for discussion of controls. Unadjusted relative risks given in parentheses. N = 59,680 native white births, plus 872 infant deaths, and 30,719 native black births, plus 1,057 infant deaths.

ing should clarify some inconsistent results found in the original Institute of Medicine study. These results, however, must also be interpreted with caution, because a variety of behavioral characteristics of mothers which have been linked to low birth weight are not included in the present analysis. Women with these characteristics may be precisely those mothers who do not seek prenatal care.

Mothers' dietary habits, for example, have long been related to subsequent birth weight.[11-14] Smoking and consumption of alcoholic beverages during pregnancy[15, 16] are additional behaviors which can endanger the newborn. Thus, while substantial relationships between prenatal care and low birth weight are indicated in Table 2, clear causal interpretations of these relationships are not possible.

One fact that should be re-emphasized is that the gestation length of the pregnancy has been controlled in these analyses insofar as gestation length may influence the number and timing of prenatal care visits: no efforts on the other hand have been made to estimate the effect of prenatal care upon gestation length. Other research, however, has indicated that birth weight is more influenced by environmental factors,[17, 18] and is also more predictive of subsequent infant problems than the fact of a short gestation.[19] Thus, a reliance upon low birth weight in the present study as the dependent variable of interest appears justified.

One further fact concerning the estimated relative risks presented in Table 2 should be explained: in some cases, intermediate levels of prenatal care appear to indicate less risk than do adequate levels of care. These differences are small in general, however, and not statistically significant, and for the moment will be interpreted as indicative of insignificant

differences in relative risk for these two categories (the addition of interactions in the following section will support this interpretation).

The coefficient estimates in Appendix B further provide evidence for the impact of a variety of other factors besides prenatal care upon low birth weight and neonatal and postneonatal mortality. Variables such as education of the parents, wedlock status, family size, and type of hospital service (a measure of continuity of care) all are found to be associated with substantial differences in outcomes over and above those related to differences in prenatal care. Thus, we are reminded that variations in health care can explain at most only a part of variations in infant mortality.

Furthermore, the percentage of low birthweight infants varied from a low of 7.1 per cent among native whites with adequate prenatal care to 11.6 per cent among native whites with inadequate prenatal care. Among native black infants, these percentages varied from 11.1 per cent among those receiving adequate prenatal care to 19.1 per cent among those receiving inadequate care. Clearly, differences in prenatal medical care can only contribute to part of the racial differences noted.

Variations in the Estimated Effects of Prenatal Care

The analyses presented thus far assumed that any effects of prenatal care upon the outcomes of interest are uniform across different types of mothers and infants. This assumption is relaxed in the present analysis, and estimates are made of interactions between background characteristics, levels of prenatal care received, and the outcome of low birth weight. Tests were made for the statistical significance of all interactions between prenatal care and those variables exhibiting a significant independent relationship to low birth weight. Within the native white population, statistically significant differences were found in the extent to which prenatal care effects varied by type of hospital service. The lack of a striking interaction between prenatal care and the variable indicating conditions observed during pregnancy fails to support earlier work by Shwartz and Vinyard which suggested that prenatal care is effective only for mothers who experience an uncomplicated pregnancy, and who deliver at term.[4] Other statistically significant interactions were found between the following variables: education of mother with observed pregnancy conditions, hospital service with birth order, hospital service with wedlock status, observed pregnancy conditions with wedlock status, and hospital service with observed pregnancy conditions.

Within the black population, a statistically significant interaction of prenatal care with the fact of observed pregnancy conditions was found. Other statistically significant interactions included: education of mother with wedlock status, age of mother with birth order, and age of mother with observed pregnancy conditions.

The estimated relative risks calculated when all these interactions are taken into account are displayed in Table 3. Inspection of this table reveals substantial differences in estimated relative risks for different populations of mothers. The greatest distinction concerns native white mothers who were

TABLE 3—Estimated Relative Risks of Low Birth Weight by Adequacy of Prenatal Care in New York City in 1968, Controlling for the Additive and Interactive Effects of a Variety of Factors‡

Population	(N)	Estimated Relative Risks[a] by Adequacy of Prenatal Care			
		Inadequate	Inter-mediate	Adequate	χ^2[b]
Total Native	59,680	1.67	1.12	1.00	
White		(1.72)	(1.02)	(1.00)	
Native White/	50,052	1.20	.96	1.00	
Private Service		(1.25)	(.96)	(1.00)	
					31.28**
Native White/	9,628	2.33	1.31	1.00	
General Service		(2.47)	(1.35)	(1.00)	
Total Native	30,719	1.85	1.08	1.00	
Black		(1.89)	(1.18)	(1.00)	
Native Black/	4,702	1.94	1.01	1.00	
with Pregnancy		(1.97)	(1.02)	(1.00)	
Conditions					
					7.37*
Native Black/	26,017	1.76	1.16	1.00	
No Pregnancy		(1.92)	(1.24)	(1.00)	
Conditions					

[a]The standard used in all cases is the Adequate Care category for each population category.

[b]χ^2 tests are the likelihood ratio statistic and indicate whether the interactions presented are statistically significant. Two degrees of freedom are associated with all these tests.

* = significant at .05

** = significant at .01

‡See text for discussion of controls. Unadjusted relative risks given in parentheses.

admitted to a general as opposed to a private hospital service. Mothers admitted on a private service are usually cared for by their private physician, and this fact is thus indicative of relatively continuous care. In contrast, mothers admitted on a general service usually experience more fragmented care, and are generally at higher risk along a variety of social and medical dimensions (see Appendix B, Tables B1 and B2). Intuitively, one would expect that this latter group could benefit relatively more from a regular program of prenatal care than could mothers who were in contact with a private physician, and this interpretation is supported by the data. It is seen in Table 3 that the estimated relative risk of low birth weight for the inadequate as opposed to adequate care categories is only 1.2 for native white mothers admitted on a private service but rises to 2.3 for native white mothers admitted on a general service—controlling for the additive and interactive effects of all other variables in the present design.

Among black women, differences in prenatal care are also associated with substantial differences in the risk of a low birth weight infant. Furthermore, black women with pregnancy conditions who receive inadequate prenatal care experience particularly great risk. This finding conforms to clinical experience, since there are a variety of maternal diseases identifiable during pregnancy which can increase the risk of subsequent prematurity and low birth weight.[1, 20] No

significant interactions of prenatal care and hospital services were found among the black population.

The causal interpretations of all of these assertions, however, are again limited by the fact that a variety of behavioral characteristics of mothers are not controlled in the analysis.

Discussion

A number of significant findings emerge from these analyses. First, prenatal care is found to exhibit little relationship to neonatal and postneonatal mortality once birth weight and other variables are controlled. Thus, if prenatal care exerts any effects upon infant mortality, it is likely that these effects occur via the relationship of prenatal care to low birth weight. Second, among native born white mothers who deliver on a private service, after controlling for a variety of selective factors, those receiving inadequate as opposed to adequate levels of prenatal care were found to experience only slightly increased risks of a low birth weight infant.

In contrast, these analyses also indicate that the minority of white mothers in the sample who deliver on general services, as well as black mothers, tend to experience a substantially increased risk of a low birth weight infant when receiving inadequate (as opposed to adequate) prenatal care. This finding may be subject to two interpretations. It could be argued that the stresses and constraints of living in poverty and the inner city not only affect some fetuses adversely (via variables not available for analysis, such as consumption of an inadequate diet, smoking, drinking, drug abuse, and other mechanisms as yet unexplored), but also affect maternal motivation to seek prenatal care. Hence, the observed relationship between lack of prenatal care and low birth weight could be partially or totally explained by this "selection" of women into prenatal care.

TABLE 4—Mothers Receiving Late (Third Trimester) or No (or Not Stated) Prenatal Care in 1969 and 1975; New York State and 37 States and the District of Columbia

Population/Year	Total Births	Births with Late, or No (or Not Stated) Prenatal Care	Percent age
New York State			
Total Births			
1969	309,408	50,006	16.2%
1975	235,608	28,604	12.1
Black Births			
1969	53,284	16,428	30.9
1975	47,498	10,678	22.5
37 States and DC			
Total Births			
1969	2,793,694	358,160	12.8
1975	2,445,896	217,886	8.9
Black Births			
1969	404,748	95,062	23.5
1975	381,072	55,182	14.5

SOURCE: Vital Statistics of the United States, 1969 and 1973

An alternative explanation would suggest that substantial numbers of women who are at such risk *do* become involved in prenatal care and subsequently alter their behavior because of this care. Thus adequate prenatal care would effect higher birth weights. Such an explanation would also argue that the various social and economic variables used as controls in the present analysis also serve as proxies for the environmental and life-style variables noted above, so that some control over these has in fact been made. Such an interpretation would support the contention of Fuchs that: "For very risky pregnancies, the quantity and quality of care available may be critical; for pregnancies that present little risk (that is, among well-educated, well-fed mothers, neither very young or very old) the quality of care may be of minor importance. . . ."[21] The estimated relationships between prenatal care and low birth weight in the present data could also reflect a mixture of both of these competing explanations; resolution of this question, however, will have to await new data which are not as limited as these data from New York City in 1968.

While the results of these analyses are thus causally inconclusive, they should serve to focus attention upon this minority of women not receiving prenatal care who are at substantial risk of producing a low birth weight infant. These results are particularly suggestive for the black population in the United States, since a main component of black-white differentials in infant mortality is the high incidence of low birth weight among black infants.[14, 22]

Certainly large numbers of expectant mothers in the United States currently receive quite excellent prenatal care, but substantial numbers are also not being served. In New York City, for example, the percentage of mothers receiving late (third trimester) or no prenatal care increased from 10.6 per cent in 1951[23] to 16.3 per cent in 1968.[6] In New York State, the percentage of mothers receiving late (third trimester) or no (or not stated) prenatal care was 16.2 per cent in 1969 and 12.1 per cent in 1975. The corresponding percentages among the black population were 30.9 per cent in 1969 and 22.5 per cent in 1975 (see Table 4). The corresponding percentages for 37 states and the District of Columbia were lower (Table 4), but the persistence of such substantial numbers is still indicative of the lack of clear national policies aimed at improving the delivery of prenatal care services.

A variety of barriers contribute to this unequal distribution of prenatal care in the United States. For young and poor mothers, who so often "fall between the cracks" of the medical and welfare system, these barriers can be particularly difficult. As of July 1, 1974, for example, 20 states did not provide prenatal care under Medicaid to first pregnancy mothers,[24] and this particular situation has persisted to the present day.

REFERENCES

1. Vaughan VC, McKay RJ: Textbook of Pediatrics. Philadelphia: W. B. Saunders Co., 1975.
2. The American College of Obstetricians and Gynecologists: Standards for Obstetric-Gynecologic Services. Chicago: The College, 1974.
3. Wells HS, Greenberg BG and Donnelly JF: North Carolina fetal
and neonatal death study. Am J Public Health. 48:1583–1595, 1958.
4. Shwartz S and Vinyard JH: Prenatal care and prematurity. Public Health Reports 80:237–248, 1965.
5. Levy BS, Wilkinson FS and Marine WN: Reducing neonatal mortality with nurse midwives. Am J Obstetric Gynecology 109:50–58, 1971
6. Institute of Medicine, National Academy of Sciences: Infant Death, An Analysis by Maternal Risk and Health Care. In: Contrasts in Health Status, Volume I, 1973.
7. Goodman LA: The multivariate analysis of qualitative data: Interactions among multiple classifications. J Am Stat Assoc 65:226–256, 1970.
8. Goodman LA: The analysis of multidimensional contingency tables when some variables are posterior to others: A modified path analysis approach. Biometrika 60:179–92, 1973.
9. Bishop YMM, Fienberg SE and Holland PW: Discrete Multivariate Analysis: Theory and Practice. Cambridge: MIT Press, 1975.
10. MacMahon B, Pugh TF and Ipsen J: Epidemiologic Methods. Boston: Little Brown and Company, 1960.
11. Antonov AN: Children born during the siege of Leningrad in 1942. J Pediatrics 30:250+, 1947.
12. Bergner L and Susser MW: Low birthweight and prenatal nutrition: An interpretive review. Pediatrics 46:946+, 1970.
13. Rush D, Davis H and Susser M: Antecedents of low birthweight in Harlem, New York City. Int J Epidemiology 1:375–387, 1972.
14. Habicht JP, Yarbrough C, Lechtig A and Klein RE: Maternal nutrition, birthweight and infant mortality In: Size at Birth. Ciba Foundation Symposium 27, 3-19, New York: Associated Scientific Publishers, 1974.
15. Fielding JE and Yankauer A: The pregnant smoker. (Editorial) Am J Public Health 68:835–836, 1978.
16. Fielding JE and Yankauer A: The pregnant drinker. (Editorial) Am J Public Health 68:836–838, 1978.
17. Gruenwald P: Pathology of the deprived fetus and its supply line. In: Size at Birth, Ciba Foundation Symposium 27, 3–19. New York: Associated Scientific Publishers, 1974.
18. Gruenwald P, Funakawa H, Mitani S, et al: Influence of environmental factors on foetal growth in man. Lancet I:1026–29, 1967.
19. Neligan GA, Kolvin I, Scott DM and Garside RF (eds.): Born Too Soon or Born Too Small, Philadelphia: Lippincott, 1976.
20. Page EW: Problems of Prematurity: Clues to Prevention. American Medical Association, National Conference on Infant Mortality. San Francisco: 44–52, 1966.
21. Fuchs VR: Who Shall Live: Health, Economics and Social Choice. New York: Basic Books, p. 37, 1974.
22. Shapiro S, Schlesinger EQ and Nesbitt REL: Infant, Perinatal, Maternal and Childhood Mortality in the United States. Cambridge, MA: Harvard University Press, 1968.
23. Baumgartner L, Pakter J: Challenge of fetal loss, prematurity and infant mortality—Assessing the local situation. JAMA 167:936–44, 1958.
24. US Department of Health, Education, and Welfare. Characteristics of State Plans for Aid to Families with Dependent Children under the Social Security Act Title IV-A. Washington, DC, USGPO, 1974.

APPENDIX A
Adequacy of Prenatal Care Defined in Terms of Timing and Quantity of Prenatal Visits, Adjusted for Gestation Length

Adequacy of Prenatal Care	Gestation (Weeks)		Number of Prenatal Visits
Adequate[a]	13 or less	and	1 or more not stated
	14–17	and	2 or more
	18–21	and	3 or more
	22–25	and	4 or more
	26–29	and	5 or more
	30–31	and	6 or more
	32–33	and	7 or more
	34–35	and	8 or more
	36 or more	and	9 or more
Inadequate[b]	14–21[c]	and	0 or not stated
	22–29	and	1 or less or not stated
	30–31	and	2 or less or not stated
	32–33	and	3 or less or not stated
	34 or more	and	4 or less or not stated
Intermediate	All combinations other than those specified above		

[a] In addition to the specific number of visits indicated for adequate care, the interval to the first prenatal visit had to be 13 weeks or less (first trimester).

[b] In addition to the specific number of visits indicated for inadequate care, all women who started their care during the third trimester (28 weeks or later) were considered to have received inadequate care.

[c] For this gestation group, care was considered inadequate if the time of the first visit was not stated.

APPENDIX B

Cross-classification tables were constructed for each of the dependent variables; these tables include all the independent variables described in the text. If the n dimensions of such a table are described by the letters ijk . . . n, the expected neonatal or postneonatal death rate (or odds of a low birthweight infant) conditional upon given levels of the independent variables may be expressed as the product of a number of parameters, written as follows:[8]

$$E \text{ (death rate}_{ijk \ldots n}) = \gamma \gamma_i^A \gamma_j^B \ldots \gamma_n^N \tag{1}$$

$$\text{where } \prod_k \gamma_k^K = 1.0, \text{ for } K = A, B, \ldots, N. \tag{2}$$

(Note: the expected death rate could also be an expected odds; as the odds become small, they approximate a rate.) The large letters, such as N, represent the different variables, and the small letters, such as n, represent the various categories of that variable. Each of the A, B, . . ., N sets of coefficients correspond to one dimension of the cross-classification table, and represent the effects of the categories of that variable upon the expected death rate.

Equivalently, one may express the natural logarithm of the expected conditional death rate as:

$$\lg E \text{ (death rate}_{ijk \ldots n}) = B + B_1^A + B_j^B + \ldots + B_n^N \tag{3}$$

$$\text{where } \sum_k B_k^K = 0 \text{ for } K = A, B, \ldots, N. \tag{4}$$

Estimates of the log-linear coefficients (of the form in (3) above) from equations predicting low birth weight, neonatal and postneonatal mortality, for both the native black and native white populations of New York City in 1968 are given in Tables B1 and B2 below. Coefficient estimates are also given for equations predicting who is delivered on a ward versus a private service and who receives inadequate prenatal care. These are maximum likelihood estimates, generated using the ECTA program (available from Leo Goodman, Department of Sociology, University of Chicago).

Some variables with statistically insignificant coefficients were dropped from the equations whose estimates appear in Tables B1 and B2. A step-down procedure was used. The coefficient estimates displayed are those obtained after these variables were dropped.

Coefficient estimates for the equations predicting low birth weight were also re-estimated with the addition of interaction terms between pairs of independent variables and the dependent variable. (Results from these analyses are displayed in Table 3.)

Tests for significant interactions were made for all pairs of variables which exhibited a significant relationship to low birth weight (as indicated in Tables B1 and B2). All of these interactions were then added to the equations, and a step-down procedure was used to arrive at the final models. The significant interactions included are described in the text.

Estimates of relative risks are derived from results of the multivariate logistic analysis as follows: for example, assume variable A has three categories, representing three levels of prenatal care

1 = inadequate
2 = intermediate
3 = adequate

Taking level 3 as the base, for any other cells j . . . n of the cross classification table we can write the expected death rates for different levels of variable A as follows:

(1) $\quad E \text{ (death rate}_{1j \ldots n}) = \gamma \gamma_1^A \gamma_j^B \ldots \gamma_n^N$

(2) $\quad E \text{ (death rate}_{2j \ldots n}) = \gamma \gamma_2^A \gamma_j^B \ldots \gamma_n^N$

(3) $\quad E \text{ (death rate}_{3j \ldots n}) = \gamma \gamma_3^A \gamma_j^B \ldots \gamma_n^N$

The relative risk of inadequate (category 1) as opposed to adequate (category 3) levels of prenatal care is thus:

$$\frac{E \text{ (death rate}_{1j \ldots n})}{E \text{ (death rate}_{3j \ldots n})} = \frac{\gamma \gamma_1^A \gamma_j^B \ldots \gamma_n^N}{\gamma \gamma_3^A \gamma_j^B \ldots \gamma_n^N}$$

$$= \frac{\gamma_1^A}{\gamma_3^A}$$

$$= e^{(\beta_1^A - \beta_3^A)}$$

Thus, estimates of relative risk are derived from coefficient estimates such as those presented in Appendix Tables B1 and B2 by simply taking anti-logs and multiplying the estimated coefficient vector $(\gamma_1^A, \gamma_2^A, \gamma_3^A)$ by the estimate: $1/\gamma_3^A$. The χ^2 tests presented in these tables indicate whether the estimated coefficients from which these risks are derived are significantly different from zero.

APPENDIX TABLE B1—Coefficient Estimates: Factors Affecting Low Birth Weight, Neonatal and Postneonatal Mortality among Native White Births in New York City in 1968

Predetermined Variables		Dependent Variables				
		Inadequate Prenatal Care	Hospital Service (Gen/Priv)	Low Birth Weight	Neonatal Mortality	Postneonatal Mortality
0-8	Education	.26	.67	−.03	.06	.71
9-11	of	.35	.47	.15	−.21	.53
12+	Mother	−.23	−.40	−.08	−.13	.13
NA		−.38 (281.18)**	−.75 (664.80)**	−.04 (24.74)**	.28 (5.33)	−1.37 (12.82)**
0-8	Education	.27	.45		.27	−.16
9-11	of	−.02	.19		−.14	.07
12+	Father	−.44	−.74		−.15	−.23
NA		.19 (249.89)**	.09 (713.48)**	(1.93)ᵃ	.02 (4.14)	.32 (4.08)
< 20	Age	.47	.99	−.06		.18
20-30	of	−.13	−.25	−.09		−.13
31+	Mother	−.33 (275.82)**	−.74 (998.71)**	.15 (31.55)**	(.10)ᵇ	−.05 (1.59)
1	Birth	−.13	−.13	.09	−.17	−.32
2	Order	−.08	−.09	−.05	.04	.20
3+		.20 (120.27)**	.21 (89.68)**	−.04 (16.57)**	.13 (11.17)**	.12 (7.65)*
Illegit / Legit	Wedlock Status	.69 (595.56)**	.98 (947.69)**	.15 (23.37)**	(.01)ᵃ	(1.86)ᵃ
1+ / None	Medical Conditions Observable During Pregnancy	.04 (3.35)	.43 (315.93)**	.46 (364.12)**	.40 (63.62)**	(.44)ᵇ
Inad / Interm / Adeq	Prenatal Care		.93 / .07 / −1.00 (2,603.77)**	.24 / −.14 / −.10 (83.75)**	.08 / −.11 / .03 (3.62)	.09 / −.09 / .01 (.83)
Gen / Priv	Hospital Service			.09 (14.67)**	.11 (4.12)*	.27 (6.11)*
< 2500 gm. / 2500 gm. +	Birth Weight				1.63 (1,508.76)**	.62 (39.51)**
χ² (degrees of freedom)		817 (563)	1387 (1713)	693 (851)	483 (1138)	340 (1713)

χ² tests are in parentheses. * = significant at .05; ** = significant at .01. Sample consists of 59,680 live births, including 4,719 low birth weight infants, plus 699 neonatal and 173 postneonatal deaths. ᵃ insignificant, dropped from analysis, ᵇ also insignificant, dropped from analysis.

APPENDIX TABLE B2—Coefficient Estimates: Factors Affecting Low Birth Weight, Neonatal and Postneonatal Mortality, for Native Black Infants Born in New York City in 1968

Predetermined Variables		Inadequate Prenatal Care	Hospital Service (Gen/Priv)	Low Birthweight	Neonatal Mortality	Postneonatal Mortality
⎡ 0–8 ⎤ 9–11 12+ ⎣ NA ⎦	Education of Mother	.02 .01 −.10 ___ .08 (20.60)**	.05 .20 −.32 ___ .07 (157.53)**	.00 .02 −.10 ___ .09 (12.24)**	.06 −.15 −.05 ___ .13 (4.12)	.33 .13 .01 ___ −.48 (5.88)
⎡ 0–8 ⎤ 9–11 12+ ⎣ NA ⎦	Education of Father	.05 .04 −.16 ___ .07 (55.73)**	.15 .31 −.42 ___ −.03 (257.05)**	.04 .00 −.09 ___ .05 (8.84)*	.11 .03 −.11 ___ −.02 (2.41)	−.05 .01 −.19 ___ .23 (8.37)*
⎡ <20 ⎤ 20–30 ⎣ 31+ ⎦	Age of Mother	.45 .00 −.45 (376.10)**	.41 .15 −.55 (276.58)**	−.06 −.05 .11 (10.82)**	(.92)[b]	.37 .05 −.42 (11.62)**
⎡ 1 ⎤ 2 ⎣ 3+ ⎦	Birth Order	−.41 .00 .41 (612.68)**	−.28 −.03 .31 (166.48)**	.05 .00 −.05 (5.66)	−.11 .09 .03 (4.40)	−.52 .18 .34 (28.50)**
⎡ Illegit ⎤ ⎣ Legit ⎦	Wedlock Status	.21 (153.84)**	.41 (256.23)**	.07 (9.43)**	(.23)[a]	(.29)[a]
⎡ 1+ ⎤ ⎣ None ⎦	Medical Conditions Observable During Pregnancy	−.07 (16.71)**	.38 (227.05)**	.21 (105.32)**	.04 (.81)	(.16)[b]
⎡ Inad ⎤ Interm ⎣ Adeq ⎦	Prenatal Care		.73 .10 −.83 (1048.45)**	.35 −.11 −.23 (223.42)**	.21 −.24 .03 (26.68)**	.17 −.13 −.05 (5.84)
⎡ Gen ⎤ ⎣ Priv ⎦	Hospital Service			(3.37)[a]	−.01 (.06)	.01 (.03)
⎡ <2500 gm ⎤ ⎣ 2500 gm + ⎦	Birthweight				1.62 (1526.28)**	.37 (31.14)**
χ^2 (degrees of freedom)		644 (563)	1535 (1713)	1163 (1713)	493 (1138)	442 (1713)

χ^2 tests are in parentheses. * = significant at .05; ** = significant at .01. Sample consists of 30,719 live births, including 4,793 low birthweight infants, plus 748 neonatal deaths and 309 postneonatal deaths. [a] = insignificant, dropped from analysis. [b] = also insignificant, dropped from analysis